What is claimed is:

CLAIMS

1. A haptic feedback interface device coupled to a host computer implementing a host application program, said interface device manipulated by a user, the interface device comprising:

a housing that is physically contacted by said user;

a sensor device detecting said manipulation of said interface device by said user, said sensor device outputting sensor signals representative of said manipulation;

an actuator coupled to said housing, said actuator operative to output a rotary force; and

a flexure coupling said actuator to said housing, said flexure being a unitary member and including a plurality of flex joints allowing a portion of said flexure to be approximately linearly moved, wherein said flexure converts said rotary force output by said actuator to said linear motion, said linear motion causing a force that is transmitted to said user.

2. A haptic feedback interface device as recited in claim 1 wherein said linear motion is approximately along an axis that is perpendicular to a planar workspace in which said interface device may be moved by said user.

3. A haptic feedback interface device as recited in claim 1 wherein said portion of said flexure is coupled to an inertial mass so that said inertial mass is linearly moved when said actuator outputs said rotary force, wherein an inertial force caused by said inertial mass is transmitted to said user through said housing.

4. A haptic feedback interface device as recited in claim 3 wherein said inertial mass is said actuator.

5. A haptic feedback interface device as recited in claim 1 wherein said portion of said flexure is coupled to a moveable contact member, said contact member being in physical contact with said user when said user is normally operating said interface device.

6. A haptic feedback interface device as recited in claim 5 wherein said contact member includes a cover portion of said interface device, said cover portion being at least a portion of a top surface of said interface device.

7. A haptic feedback interface device as recited in claim 1 wherein said flexure includes a rotating member coupled to a rotating shaft of said actuator, wherein said rotating member is coupled to a linear moving portion of said flexure by one of said flex joints.

8. A haptic feedback interface device as recited in claim 7 wherein said flexure includes two arm members coupling said linear moving potion to a stationary portion of said flexure, wherein each of said arm members is coupled to said linear moving portion by one of said flex joints.

9. A haptic feedback interface device as recited in claim 1 wherein said flexure includes a central member coupled to a rotating shaft of said actuator and two branch members arranged approximately in a Y-configuration, wherein one of said flex joints is provided between each of said members and coupled members.

10. A haptic feedback interface device as recited in claim 9 wherein two flex joints are provided on each of said branch members and at least one flex joint is provided on said central member.

11. A haptic feedback interface device as recited in claim 4 wherein said flexure includes:

a rotating member coupled to said housing by a flex joint, and

two arm members, each arm member coupling said actuator to said housing via at least one flex joint.

12. A haptic feedback interface device as recited in claim 11 wherein said rotating member is coupled to said housing by two flex joints, and wherein each of said arm members couples said actuator to said housing by two flex joints.

13. A haptic feedback interface device as recited in claim 1 wherein said actuator is driven bi-directionally to produce pulse or vibration sensations to said user.

14. A haptic feedback interface device as recited in claim 1 wherein said flexure includes at least one stop to prevent motion of an actuator shaft of said actuator past a desired fraction of a full revolution.

15. A haptic feedback interface device as recited in claim 1 wherein said interface device is a handheld interface device.

16. A haptic feedback interface device as recited in claim 1 wherein said interface device is a remote control device.

17. A haptic feedback interface device as recited in claim 1 wherein said interface device is a mouse.

18. A haptic feedback interface device as recited in claim 17 wherein said linear motion is correlated with a graphical representation displayed by said host computer, wherein a position of said mouse in said planar workspace corresponds with a position of a cursor displayed in said graphical representation.

19. A haptic feedback interface device as recited in claim 3 wherein said linear motion provides a pulse correlated with the interaction of a user-controlled cursor with a graphical object displayed in a graphical user interface.

20. A haptic feedback interface device as recited in claim 19 wherein said pulse is output with a magnitude dependent on a characteristic of said graphical object with which said cursor interacts.

21. A haptic feedback interface device as recited in claim 20 wherein said characteristic of said graphical object is a type of said graphical object, wherein said type includes one of an icon, a window, and a menu item.

22. A haptic feedback interface device as recited in claim 20 wherein said pulse is output when said cursor moves between menu items in a displayed graphical menu.

23. A haptic feedback interface device as recited in claim 1 wherein said linear motion is included in a force sensation, said force sensation being one of a pulse, vibration, and texture force.

24. A haptic feedback interface device as recited in claim 1 further comprising a microprocessor, separate from said host computer, coupled to said sensor and to said actuator, said microprocessor operative to receive host commands from said host computer and output force signals to said actuator for controlling said rotary force, and operative to receive said sensor signals from said sensors, process said sensor signals, and report locative data to said host computer derived from said sensor signals and indicative of movement of said interface device.

25. A haptic feedback interface device as recited in claim 17 wherein said actuator outputs said force in response to a command received by said mouse from said host computer.

26. A haptic feedback interface device as recited in claim 17 wherein said sensor device includes a ball that frictionally contacts a surface on which said mouse is moved by said user.

27. A haptic feedback interface device as recited in claim 17 wherein said sensor device includes an optical sensor that detects motion of a surface on which said mouse is moved relative to said housing of said mouse.

28. A haptic feedback interface device as recited in claim 3 wherein said interface device is operated on a pad, said pad providing compliance between said device and a hard surface supporting said pad, wherein said compliance magnifies said inertial force.

29. A haptic feedback interface device as recited in claim 4 wherein said actuator is positioned such that a rotating shaft of said actuator rotates about an axis approximately perpendicular to a surface on which said interface device rests.

30. A haptic feedback interface device coupled to a host computer implementing a host application program, said interface device manipulated by a user, the interface device comprising:

a device housing that is physically contacted by said user;

a sensor device detecting said manipulation of said interface device by said user, said sensor device outputting sensor signals representative of said manipulation;

an actuator coupled to said device housing, said actuator operative to output a force; and

a mechanism coupling said actuator to said device housing, said mechanism allowing said actuator to be moved with respect to said device housing, wherein said actuator acts as an inertial mass when in motion to provide an inertial force that is transmitted to said user.

periodic motion periodic

31. A haptic feedback interface device as recited in claim 30 wherein said actuator is approximately linearly moved with respect to said device housing, said movement caused by said force output by said actuator.

32. A haptic feedback interface device as recited in claim 31 wherein said force output by said actuator is a rotary force.

33. A haptic feedback interface device as recited in claim 30 wherein said actuator approximately linearly moves approximately along a z-axis substantially perpendicular to an x-y plane in which said user can move a manipulandum of said interface device.

34. A haptic feedback interface device as recited in claim 30 wherein said actuator is coupled to a contact member such that when said actuator is moved, said contact member is moved, wherein said user physically contacts said contact member in normal operation of said interface device, said contact member transmitting a contact force to said user while said inertial force is transmitted to said user.

35. A haptic feedback interface device as recited in claim 34 wherein said contact member includes a cover portion of said interface device, said cover portion being at least a portion of a top surface of said interface device.

36. A haptic feedback interface device as recited in claim 30 wherein said mechanism includes mechanical rotary bearings.

37. A haptic feedback interface device as recited in claim 30 wherein said mechanism includes a flexure having at least two flex joints.

38. A haptic feedback interface device as recited in claim 37 wherein said flexure includes:

a rotating member coupled to said housing by a flex joint, and

two arm members, each arm member coupling said actuator to said device housing via at least one flex joint.

39. A haptic feedback interface device as recited in claim 38 wherein said rotating member is coupled to said device housing by two flex joints, and wherein each of said arm members couples said actuator to said housing by two flex joints.

40. A haptic feedback interface device as recited in claim 37 wherein said flexure includes at least one stop to prevent rotation of a shaft of said actuator past a desired fraction of a full revolution.

41. A haptic feedback interface device as recited in claim 30 wherein said actuator is moved bi-directionally to produce pulse and vibration sensations to said user.

42. A haptic feedback interface device as recited in claim 30 wherein said interface device is a handheld interface device.

43. A haptic feedback interface device as recited in claim 42 wherein said interface device is a remote control device.

44. A haptic feedback interface device as recited in claim 33 wherein said interface device is a mouse.

45. A haptic feedback interface device as recited in claim 44 wherein said inertial force is correlated with a graphical representation displayed by said host computer, wherein a position of said mouse in said planar workspace corresponds with a position of a cursor displayed in said graphical representation.

46. A haptic feedback interface device as recited in claim 44 wherein said inertial force is a pulse correlated with the interaction of a user-controlled cursor with a graphical object displayed in a graphical user interface.

47. A haptic feedback interface device as recited in claim 30 wherein said mechanism includes a travel limiter for limiting said movement of said actuator to a desired range of movement.

48. A haptic feedback interface device as recited in claim 30 wherein said actuator is a rotary DC motor.

49. A haptic feedback interface device as recited in claim 33 wherein a rotating shaft of said actuator is coupled to a flexure arm of said mechanism, said flexure arm including said at least one flex joint, said flexure arm coupled to a grounded portion that is coupled to said device housing and is flexibly coupled to a carriage of said mechanism, said carriage holding said actuator.

50. A method for providing haptic sensations to a user manipulating an interface device, said interface device coupled to a host computer, the method comprising:

detecting said manipulation of said interface device by said user, said sensor device outputting sensor signals representative of said manipulation;

outputting a force using an actuator, wherein said actuator is coupled to a housing of said interface device;

moving said actuator with said force output by said actuator, wherein said actuator acts as an inertial mass when in motion to provide an inertial force that is transmitted to said user.

51. A method as recited in claim 50 wherein said force is output based on information received by said interface device from said host computer.

52. A method as recited in claim 50 wherein a mechanism coupling said actuator to said device housing allows aid actuator to be moved with respect to said device housing.

53. A method as recited in claim 52 wherein said mechanism includes a flexure having at least one flex joint.

54. A method as recited in claim 50 wherein said actuator is moved approximately linearly.

55. A method as recited in claim 50 wherein said force output by said actuator is a rotary force.

56. A method as recited in claim 50 wherein said actuator linearly moves approximately along a z-axis substantially perpendicular to a planar workspace in which said user can move a manipulandum of said interface device.

57. A method as recited in claim 56 wherein said inertial force is correlated with a graphical representation displayed by said host computer, wherein a position of said manipulandum in said planar workspace corresponds with a position of a cursor displayed in said graphical representation.

58. A method as recited in claim 53 wherein said actuator is biased to an origin position by a spring compliance when said actuator is at rest.

59. A method as recited in claim 58 wherein when said force is output, said actuator is moved initially in a direction in which a distance from said origin position to a first range limit of said movement of said actuator is greater than a distance from said origin position to a second range limit of said movement of said actuator.

60. An actuator assembly for use in a haptic feedback interface device coupled to a host computer implementing a host application program, said interface device manipulated by a user, the actuator assembly comprising:

an actuator having an actuator housing and a rotating shaft, said actuator housing coupled to a housing of said interface device, said actuator operative to output a force; and

a mechanism coupling said actuator to said housing, said mechanism allowing said actuator housing and shaft to be moved with respect to said device housing, said movement caused by said output force, wherein said actuator acts as an inertial mass when in motion to provide an inertial force that is transmitted to said user of said interface device.

61. An actuator assembly as recited in claim 60 wherein said actuator moves approximately linearly.

62. An actuator assembly as recited in claim 60 wherein said force output by said actuator is a rotary force.

63. An actuator assembly as recited in claim 60 wherein said mechanism allowing said actuator movement is a flexure including at least one flex joint.

64. An actuator assembly as recited in claim 63 wherein said rotating shaft of said actuator is coupled to a flexure arm including said at least one flex joint, said flexure arm coupled to a grounded portion that is flexibly coupled to a carriage, said carriage holding said actuator housing.

65. An actuator assembly as recited in claim 60 wherein said mechanism includes a travel limiter for limiting said movement of said actuator to a desired range of movement.

66. An actuator assembly as recited in claim 60 wherein said actuator is coupled to a contact member such that when said actuator is moved, said contact member is moved, wherein said user physically contacts said contact member in normal operation of said interface device, said contact member transmitting a contact force to said user.